
Climate Change and Society

Speculation, Construction and Scientific Investigation

Eugene A. Rosa

Washington State University

Thomas Dietz

George Mason University

abstract: This article traces the long intellectual history that seeks to understand the recursive relationship between variations in the Earth's climate and variations in social structure and cultural practices. Contemporary sociological investigations of this theme have evolved along two paths: the neo-idealistic orientation of social constructivism and a neo-realist orientation comprising two complementary approaches. Both orientations are explicated and evaluated, leading to a conclusion that provides programmatic directions.

keywords: climate change ♦ constructivism ♦ cultural practice
♦ neo-realist orientation ♦ social structure

Introduction

Climate shapes human activity. Human activity shapes climate. This article critically evaluates these propositions, overviews our sociological understanding of them, and concludes with a programmatic statement of the role of sociology in understanding climate-society interactions. We begin with a brief overview of basic scientific principles that underpin the current understanding of climate change. We then develop the climate-society theme by addressing three questions.

1. *What are the intellectual antecedents to current thought about the relationship between climate and society?* Our answer is, on the one hand, that fascination with and speculation about the reciprocal shaping of climate and

International Sociology ♦ December 1998 ♦ Vol 13(4): 421-455
SAGE (London, Thousand Oaks, CA and New Delhi)
[0268-5809(199812)13:4;421-455;006614]

VISIT...

LANZAROTE
Caliente.COM

society are nearly coeval with written thought itself. On the other hand, disciplined inquiry into the connection has a much shorter, incipient history.

2. *What are the principal sociological responses to the threat of global climate change (GCC) claimed by natural scientists?* An undeniable fact is that climate has an impact on the entire globe and is the basis of all life forms. As such, it is one of the most fundamental physical variables that penetrates social life. There are, therefore, a wide range of sociological entry points for understanding the relationship between climate and society. We identify and discuss the entry points within two principal sociological orientations – neo-realist and interpretive – whose roots have distant beginnings and which continue to distinguish two broad styles for conducting social inquiry.
3. *What are some directions that sociology might take in providing fruitful contributions to an understanding of the relationship between climate and society, and between social activities and climate change?* Our answer to this question is largely prefigured by the two sociological lines of research that emerged to address climate change issues. The neo-realist position presupposes that the epistemic (scientific) consensus over global climate and related environmental changes is relatively unproblematic. Accordingly, sociology can make significant contributions to an understanding of the recursive relationships between climate and society. We delineate ongoing and emergent approaches seeking to provide the analytic base for answers to this question and conclude with a list of research directions that we believe should direct the inquiry. The interpretive or social-constructivist orientation is far more skeptical of the validity of the knowledge claims of climate science. Since that science is studded with uncertainty, there is also a useful role for the social-constructivist tradition in understanding a much different facet of global climate change, namely the cultural and social processes involved in the production and interpretation of climatic science and societal awareness and response to it.

Climate as a Global Life-Support System: Scientific Fundamentals

The capacity to support life on earth – and, therefore, all societies – depends on the moderating influences of gases that envelop the planet, warm its surface and protect it from harmful radiation. All plant, animal and human life on the planet is dependent upon the warming capacity of these gases, referred to as the 'Greenhouse Effect', for maintaining a habitable climate.¹ Indeed, it is this greenhouse phenomenon that accounts for the abundance of life on earth and the absence of life on its closest

planetary neighbors. This is sometimes referred to as the 'Goldilocks effect': the greenhouse of Venus makes that planet too hot, while the greenhouse of Mars makes it too cold; Earth's temperature, like Goldilocks' porridge, is just right.

For most of its 4 billion year history the Earth's envelope of greenhouse gases has comprised a proper mix of gases to maintain the natural balance necessary for regulating temperature to life-supporting levels. Now, due in large part to greater sophistication in the modeling of climatic patterns, there is increasing depth to our knowledge of global climate resulting in a growing concern that human activities may be having substantial impact on this propitious mix. The global mean temperature has increased over the last century by between 0.3 and 0.6° Celsius (IPCC, 1996). The 1980s were the warmest decade recorded on a global scale (Mahlman, 1989), the mean global temperatures in 1990 and 1995 were the warmest ever recorded (Hansen, 1996), and humans may be altering the atmosphere in ways that will bring on an irreversible climate change (Bruce et al., 1996; Houghton et al., 1996; Watson et al., 1996). Were such change to obtain, and depending on its magnitude, it could challenge the sustainability of many ecosystems and all forms of social organization – human and non-human alike.

The most abundant greenhouse gas is carbon dioxide (CO₂).² It has long been speculated that changes in the CO₂ composition of the atmosphere could lead to global warming. In modern times this speculation has been disciplined with empirical investigation, sophisticated computer models and other elaborate heuristics and analytic aids. Nevertheless, the difficulty of detecting and predicting climate change, one of the most daunting scientific tasks in history, cannot be exaggerated. General circulation models that mimic climatic systems are generally adequate for preindustrial times when anthropogenic (human-induced) influences were far less pronounced and impacts tended to be local. Estimates of present and future patterns are far more difficult to make, subsume numerous uncertainties and require an understanding of a climatic system that is complex and dynamic. Indeed, none of the computer models can yet reliably simulate the present climate (Kerr, 1997).

State-of-the-art scientific monitoring has clearly demonstrated the accumulation in the atmosphere of the main greenhouse gases (Boden et al., 1994). Since preindustrial times, from around 1750, the accumulation of these gases has

... led to a positive *radiative forcing* of climate, tending to warm the surface and to produce other changes in climate. The atmospheric concentrations of greenhouse gases, *inter alia*, carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) have grown significantly: by about 30%, 145% and 15% respectively. (IPCC, 1996: 21)³

Results such as these are leading to the gradual emergence of a scientific, epistemic consensus that concludes, in the oft-repeated words of the recent IPCC (1996: 22) report that 'the balance of evidence suggests a discernible human influence on global climate'.⁴

Projections of future climate change are typically modeled as a function of economic and energy growth, the rate at which humans reproduce, emit greenhouse gases (especially CO₂), use the land and introduce technological and other changes. To capture the sensitivity of climate to human actions, the most credible projections of climate change are presented as a range comprising low-, mid- and high-range estimates. The most comprehensive of these projections is that of the IPCC (1996) whose low, mid and high estimates to the year 2100 are 1°, 2° and 3.5°C respectively. Even with the lowest of these projections, there is a threat of disruption to atmospheric and oceanic systems that regulate weather, making a number of threatening bio-geophysical changes likely and consequent social changes almost a certainty.

Terrestrial and aquatic ecosystem impacts also can be expected, such as a reduction in ecosystem services, reductions in biological diversity and the displacement or, in some cases, the extinction of species. If GCC is realized, it will be uneven in distribution, with the expectation that the poles will warm more than equatorial regions, and the continents more than areas of deeply circulating ocean. Thus, at even the lowest projection of 1°C mean temperature change an alteration in the growth and regeneration rate of forests can be expected, and at the mid-range level a sizable proportion of the forested regions of the world will be affected significantly. Increases in temperature will likely be accompanied by melting glaciers and ice sheets and rising sea levels, thereby altering significantly many coastal areas while threatening some areas of the world with inundation. Similarly, permafrost and snow cover will be affected, contributing to changes in the global hydrological and other bio-geochemical cycles (IPCC, 1996).

An increased global temperature will also lead to an accelerated hydrological cycle and likely result in severe droughts and flooding in areas which are now productive farming regions. Other areas currently less productive, however, might benefit from such a change. Significant effects could be experienced in national and global food supplies, trade imbalances, the overall world economy, the spread of tropical diseases, hurricanes and the structure of political alliances (Silver and DeFries, 1990).

These examples are reasonable extrapolations of impacts, not explicit forecasts. Neither our state of general sociological knowledge, nor our knowledge of the relationship between climate and society, allow us to make precise predictions of the social changes that would likely follow a change in climate. Nevertheless, one undeniable fact is this: a propitious

climate is essential to human life, and climate is intimately embedded within human ecosystems, so that there is good reason to expect fundamental changes to society from climate change and from resultant ecosystem impacts.

Climate and Society: Large Lenses

The idea that climate shapes 'big structures and large social processes' is, at one level of abstraction, unassailable. Few would argue against the observation that the cyclical advance and retreat of glaciers during the Ice Ages of the Pleistocene profoundly affected the geographic distribution and the social-economic organizations of our ancestors. Few, too, would argue that the end of social life on Greenland was not due to an abrupt climatic change. And few would claim that the distribution of farming and harvesting practices around the world is not directly tied to climate.

At an even more historically refined level of focus, arguments are emerging that implicate climate in large-scale sociohistorical processes. For example, a recent analysis of the climatic history of the Middle East challenges the long-held view that social, geopolitical processes created desertification – created, that is, the region's signature sand dunes (Issar, 1995). Rather, the evidence shows that it may have been major climatic changes that created desertification and other ecological changes, stimulating mass migrations and setting in motion major social and geopolitical changes. On this view the dunes forced farmers out, rather than farmers forcing the dunes in.⁵

It is these obvious – and, therefore, prosaic – examples of the putative relationship between climate and society that lead us to the more subtle and more challenging questions where unanimity is far rarer. Key questions are: how are social structure and social life tied to climate in the contemporary era, and what would be the likely impacts to these social entities if climate were to change? While such questions have often emanated from outside the sociological community – from physical scientists and policymakers, for example – they go to the core of sociological inquiry. It is only through a more refined understanding of the recursive relationships between climate and human activities that we can hope to anticipate broad societal impacts if the suspected warming of climate were realized.

Climate and Society: Historical Antecedents

Speculation about geographical and climate links to society is as old as recorded thought itself. Versions of this theme can be found in ancient China in the work of philosophers Confucius, Lao-Tse and Mencius. Similar veins of thought can be found as well among Persian thinkers and

learned Indians (Sorokin, 1928; Becker and Barnes, 1961). The theme can also be traced to the beginnings of written occidental thought. 'For example, in classical Greece, Hippocrates suggested in his treatise on "Air, water, and places" that knowledge about climate ought to be used to explain the psychology and physiology of humans' (von Storch and Stehr, 1997: 66). Later in western thought, Montesquieu wrote: 'The law of Mohammed, which prohibits the drinking of wine, is ... fitted to the climate of Arabia' (Montesquieu, 1962: Bk XIV, 10). Writing during the same era, Rousseau, imbued with the Enlightenment spirit on the unity and natural equality of all humankind, argued that differences among people were 'artificial', merely conventional or accidental due to differences in, for example, climate (Manicas, 1987: 54).

The distinguished German historian Johann Gottfried Herder saw climate as crucial in the shaping of peoples and civilizations: 'The constitution of their body, their way of life, the nature of work and play ... indeed their whole mentality are climatic' (Herder, 1969: 285). Following on the heels of Herder's writings were those of the French utopian socialist Charles Fourier. Without a doubt Fourier was the most uninhibited and flamboyant of the climate-society speculators. Fourier saw the world, not progressing as was the dominant view of the time, but as hopelessly disorganized, with civilization in relentless retrograde. He argued in 1822 that the declining material conditions on Earth were affecting climate; that the vices of civilization were leading to the 'excitation of hurricanes and all sorts of climatic excesses' (quoted in Beecher, 1986: 197).⁶ The spread of settlement and the cultivation of the Earth had increased the Earth's temperature and, if continued, would result in a melting of the polar ice caps (Beecher, 1986).⁷

One of the most deterministic accounts of the role that climate plays on society was American geographer Ellsworth Huntington's *Civilization and Climate*, published first in 1915. A particular significance of Huntington's work was that he went beyond earlier speculations based upon casual observations by introducing the quantitative analyses of statistical data. His fundamental thesis was that changes in temperature and climate determine the ebb and flow of civilizations. Civilization is only possible where climatic conditions are favorable. Initially very popular with professional geographers and the public at large, the thesis was abandoned in the 1930s as part of a general rejection of deterministic theories of every stripe,⁸ and specifically as a rejection of climatic and geographic theories that could (and, in many cases, did) support racial determinism, nationalism and colonialism.

From Analogy to Science

Speculation is one species of thought; systematic investigation an entirely different one. Systematic concern with climatic impacts on society has

alternatively attracted social thinkers and physical scientists. At about the same time (1822) that Fourier was issuing grand proclamations about climate's role in the end of civilization, another Frenchman was instrumental in initiating the transition from speculation to analysis. Physicist Jean-Baptiste Fourier (the same last name by coincidence) postulated that the Earth was kept warm because 'air traps heat, as if under a pane of glass' (Weart, 1992: 19). Over the next 60 years, building upon this same 'greenhouse' analogy, others showed that CO₂ and other gases constituting the Earth's atmosphere were responsible for maintaining the planet's warmth by trapping heat from the sun.

This growing recognition of the importance of the relationship between the composition of the atmosphere and climate, coupled with the recognition that climate is not a constant, established the dichotomy that frames contemporary concerns about climate. The dichotomy distinguishes between natural and anthropogenic (human-induced) sources of climate change. The composition of greenhouse gases at a global level is presumed to have been, for most of the Earth's recent history, in the proper balance to regulate temperature and climate at the Earth's surface.⁹ The natural composition of gases is typically seen to be beyond human intervention. In contrast, it is the anthropogenic sources, that is human activities, that are a cause for concern and, perhaps, a cause for remediation.

Despite the highly speculative tone and incredulity of socialist Charles Fourier's message, it did contain an element of prescience. For unlike his predecessors, whose causal thinking ran from climate to society, Fourier reversed the sequence, thereby shifting the focus to the anthropogenic basis of climate change. The full impact of this innovation is difficult to assess, but one significant influence is clear: the works of Fourier were an important source for Swedish geochemist Svante Arrhenius, one of the most distinguished scientists of his era¹⁰ (Elzinga, 1997).

In 1896, Arrhenius, building on the knowledge that the Earth's atmosphere was responsible for its climate, wrote a now famous paper on the cause of Ice Ages. This was perhaps the first systematic inquiry into the impacts on climate from an alteration of the gases constituting the atmosphere. In particular, using the spectroscopic data that had become available, he made an estimated 10,000–100,000 calculations by hand (Crawford, 1996) to assess what would happen to the climate if the amount of CO₂ in the air doubled.¹¹ He concluded that this amount of CO₂ in the air could warm the world by 4–6°C, an estimate not markedly different from some scientific estimates of 1.0–4.5°C. But he thought that increases in CO₂ levels at that time were primarily due to volcanic activity and that the resulting slow warming would improve living conditions and crop yields.

What is striking, in retrospect, is his estimate that CO₂ in the atmosphere

due to industrial output – a large anthropogenic source – had already reached a level comparable to the amount due to natural circulation. Striking, too, was the implication that global climate was no longer shaped by natural processes alone, but was being perturbed by anthropogenic sources – especially industrialization.

Long Processes, Huge Comparisons

In the recent upsurge of macro-social, macro-historical writings, the role of climate has loomed large. In his development of world systems theory, for example, Wallerstein (1974) points to climate as one of three key physical factors (the other two being the Black Plague¹² and soil conditions) that led to the crises in western feudalism and to the subsequent emergence of capitalism. Similarly, Braudel (1979) and others of the *Annales* School (e.g. LeRoy Laudrie, 1971) document key climatological events that led to the downfall of feudalism and laid the foundation for the modern social system. Europe experienced a general cooling from around the 13th century onward, what has come to be known as the 'little ice age', reaching its peak in the reign of Louis XIV (1643–1715).¹³ Indeed, the decade of the 1690s was the coldest for 700 years, leading Braudel (1979: 49) to claim that the little ice age 'was more of a tyrant than the Sun King'.

While these accounts of world history do incorporate the importance of climate, they neither reflect a larger recognition of the importance of climate in sociological thinking nor provide specific guides to empirical research. There is an inherent, unresolvable asymmetry in our retrospective understanding of large-scale climate and society connections in comparison to our present and future understanding of them. We are reasonably well positioned to make historical estimates of climatic variation and to postulate plausible explanations of their sources and consequences. But the dramatically different features of the contemporary world make it difficult to draw operationally useful analogies from the past. The challenge for sociology, then, is to identify or develop orientations that are sociologically informed but capable of export to ecological contexts, such as climate change. It is to this challenge that the remainder of this article is devoted.

Sociological Response to the Threat of Global Climate Change

Fundamental physical processes, like climate, are unavoidably ubiquitous. Indeed, they are so ubiquitous that unless we are prompted they recede from our conscious analytic awareness. Similarly, they are typically ignored in sociological analysis – taken to be a background constant to social processes. Once climate becomes 'socialized', as prompted by the

recent scientific concern over significant changes in climate, the background constant may be reconceptualized as a physical variable with potential influence on social life. Because the reconceptualization involves so fundamental a physical variable, it perforce cuts across a wide range of social processes and institutions. There is, therefore, grist for nearly every sociological mill.

Accordingly, global climate change has attracted a variety of sociological orientations and research directions.¹⁴ Despite this wide variation, the orientations fall into one of two general categories: a neo-realist category and an interpretive category.¹⁵ For the neo-realist orientation the scientific consensus about climate change either is taken, more or less, as an unproblematic given or the topic of climate change is viewed as a stimulating context for extending our knowledge of human ecosystems. The sociological task, then, is to identify, to theorize and to model the anthropogenic sources of climate change, as well as the impacts of climate change on societies. For the interpretive orientation, a version of neo-idealism, the emergence of GCC and other global environmental issues as a social problem is the core question of interest: what social conditions and what social actors created this global concern? This question is posed in the tradition of the sociology of knowledge and addressed within a social-constructivist framework.

Different Types of Scientific Knowledge

Before examining the alignment between the two sociological orientations toward the science of GCC, it is useful to identify different types of scientific knowledge. We can distinguish three different types: knowledge at the *core* of an established scientific discipline; research at the *frontiers* of that discipline; and research at scientific *horizons*.¹⁶ Cole provides an apt description of the core:

... [it] consists of a small set of theories, analytic techniques, and facts which represent the given at any particular point in time. If we were to look at the content of courses taught advanced undergraduate students or first-year graduate students in a field such as physics, we would acquire a good idea of the content of physics' core of knowledge. (Cole, 1992: 15)

While the core is the starting point for all erstwhile scientists, advanced training and professional standing are geared to conducting research. Since science is self-conceived to be cumulative, and since issues in the core are, by definition, universally believed to be resolved, disciplinary frontiers are continually reshaped by ongoing research. The frontiers of a given discipline, then, are nearly coterminous with all the current research being conducted in that discipline.

Scientific horizons may be thought of as not just the next incremental

extension from a disciplinary core to its frontiers and beyond, but as a sizable leap beyond the core. There are two typical ways that new horizons are established. The more common of the two is when researchers at the frontiers of a given discipline generate or encounter interesting problems for which their parent discipline has limited purchase, but where promise lies in a neighboring discipline. When this is sufficiently recognized, it generates fruitful hybridizations, such as the fields of biochemistry, biophysics, neurobiobehavioral science and other emergent scientific fields. A second way is to rediscover the tractability of an old problem with new tools, discover a new problem, or conceptualize a problem at an entirely new level of abstraction: much smaller or much larger. GCC qualifies as a horizon science because it comprises many of the features of the second way that horizon science is created. Indeed, it appears to be an exemplar of this type of science.

Realism and Social Constructivism

The tripartite scheme of types of science is a useful way for assessing the appropriateness of the two sociological orientations to climate change. Similar to Cole (1992), and consistent with Rosa's (1998) argument for the epistemological hierarchy of knowledge claims, we posit that social constructivism is least applicable at the scientific core¹⁷ and progressively more applicable as the focus moves away from the core to frontiers and to horizons. This is due, in large part, to the intellectual quest of scientific investigation. One version of that quest is that it 'is the search for unity in hidden likenesses' (Bronowski, 1956: 13). That search becomes increasingly challenging as the evidence for uncovering such likenesses becomes less and less 'ostensible and repeatable' (Rosa, 1998), and where subtlety prevails.

Global climate change research is characterized by such conditions, namely that evidence, if it exists at all, is far from ostensible and not necessarily repeatable. Furthermore, climate comprises an extremely complex set of relations within a dynamic system. So, unlike core, frontier or even some other types of horizon science, climate change research in the biophysical sciences does not enjoy the same presumed correspondence between theory and empirical evidence as do those other types. Instead, it must rely on complex simulation models that adopt fundamental laws (from core science), such as Newton's laws of motion and the various gas laws, and convert those laws into mathematical equations that can be applied to each of tens of thousands of spatial cells representing the planet's atmosphere. Modeling with the tens of thousands of equations requires the use of one of the handful of supercomputers in the world. The most sophisticated of these models, whose results are viewed as most authoritative, are the general circulation models (GCMs) that hierarchically nest data from various subsystems.

Model calibration is accomplished by comparing model outputs of retrospectively calculated global temperatures with historical data on past global temperatures – a form of backcasting. There is no way to empirically validate the model's predictions of future climate, until sometime into the future – if then. The models, therefore, are more like idealizations rather than approximations of the processes they seek to understand. Furthermore, because of vast gaps in available data (such as on cloud behavior), GCMs may best be thought of as 'heuristic devices rather than reality maps' (Elzinga, 1997: 79). On these and other grounds, climate change qualifies as an exemplar of horizon science and, therefore, is especially amenable to a constructivist orientation. Indeed, climate change has attracted considerable attention from the interpretive orientation of constructivists, a point to be discussed in a later section.

The Neo-Realist Orientation

The neo-realist orientation, with roots in materialism, views the socially constructed claims or the culturally discoursed aspects of human life as a transcendent structure which rests upon a foundation that presupposes a material world independent of percipient human actors. This orientation underpins the understanding of society via scientific methods. This orientation also underpins the historical materialism tradition where the political and cultural features of social life are viewed as a 'superstructure' ultimately dependent upon the material and economic base of societies. The first version of this orientation guides social 'scientific' analyses of climate change while the second guides the political economy of environment–society interactions.

Social 'Scientific' Analyses of GCC: No Regrets

Our position is that active involvement by human ecologists and environmental sociologists in research on GCC is supportable at several levels of abstraction, from broad to narrow, covering meta-methodological, theoretical and analytical domains. If one proper role for environmental sociology, as science rather than the study of science, is to understand and contribute to our understanding of the recursive interaction of humans and environments, then GCC is a worthy catch over which to throw our nets. It is global in perspective, has wide-ranging potential impacts to societies and is concerned with fundamental processes. Indeed, as a focal point for research toward a deeper understanding of the ecological dependence of societies, it holds potential for contributing to general sociological inquiry.

Global climate change as a topic provides, we argue, a 'no regrets' (Abelson, 1990; Aldhous, 1990) justification for developing theory and

conducting research.¹⁸ The principal greenhouse gas implicated in global warming is CO₂, due primarily to the burning of fossil fuels. Our current state of theoretical knowledge tells us that fossil fuels are finite, meaning industrial and industrializing societies must – sooner or later – wean themselves from this energy source. Insofar as concern over climate change directs us to understand the anthropogenic basis of fossil fuel use, the resulting theoretical enrichment is worth its weight of effort whether the climate is changing or not.¹⁹ A reduction in the rate of fossil fuel use would, irrespective of climate change, preserve an essential finite resource while contributing to a reduction in air pollution – both important elements in the sustainability of societies.²⁰

Climate change is principally concerned with the extent to which anthropogenic activities are perturbing the natural climatic cycles in untoward ways. Defining the GCC problem as one whose roots are in human activities, in effect, can relocate the arena of expertise from the traditional sciences to the social sciences. We believe that sociology (and the social sciences more generally) have developed the substantive expertise and analytic sophistication to take on this challenge. In the next section we explicate approaches taken to accomplish this.

Neo-Realist Research Programs

There are two neo-realist approaches to climate change as noted above, and each has spawned a research program. Both take the potential of climate change as a given or as an important intellectual challenge, and have responded by attempting to model its 'driving forces' (proximate causes). Most of the work of both research programs has focused on national emissions of CO₂ and other greenhouse gases. One program, emphasizing that understanding of climate change must be based on interdisciplinary approaches, links sociological insights to a model familiar to biophysical scientists. For reasons we note later, we call this the STIRPAT approach. The other program, from world systems theory, draws on a long tradition of sociological work on the global political economy. While these two research programs have developed independently, they are complementary, and we expect that in the near future they will converge and offer stronger insights into the driving forces of climate change than either could alone.

Driving Forces

The term 'driving forces' – common parlance in discussions of global environmental change, and of climate change in particular – can be troubling to social scientists. The term refers to the proximate causes of global environmental change. Land use and industrial metabolism (the total flow of goods in and out of production processes) are the most often mentioned

forces. But most discussions also incorporate the factors assumed to drive land use and industrial metabolism, including a variety of social, political, economic, technological and cultural variables (Stern et al., 1992). The idea of driving forces originated with modeling efforts and the need to incorporate some social variables into understanding the dynamics of climate change. For the social scientist, the concept seems too mechanistic; it does not capture the nuances of human agency, with its reflective action, structural constraints and the complexity of human response and adaptation to change – even change that is anticipated (Stern et al., 1992).

While the term 'driving forces' may not be familiar to sociology, it does point sociologists toward an important question: why is there spatial and temporal variation in the human activities that disrupt the biophysical environment? And in particular, why are there national variations in the emissions of CO₂ and other greenhouse gases?²¹ The STIRPAT and world systems research programs are efforts to provide sociological answers to these questions.

IPAT to STIRPAT

An environmental impact model called the IPAT model was proposed in the early 1970s in a debate between Barry Commoner and Paul Ehrlich and John Holdren.²² The model is an accounting equation:

$$I = P \times A \times T$$

where I is a measure of environmental impact, P is population size, A is affluence per capita and T is a technology term. Since affluence per capita is multiplied by population, the first two right-hand terms become total affluence. This means that T is measured in units of impact per unit affluence.²³ If affluence is defined in economic terms, for example by substituting gross domestic product (GDP) per capita for A, then the product P*A becomes total GDP. T is then equal to I/(P*A) or impact per dollar of GDP. While the IPAT model has many limitations, the focus it places on accounting for the dimensions that translate human actions into environmental impacts is one of its valuable features. By definition, T accounts for all factors, other than population and affluence, that affect the environment. In a sense, all of sociology is captured by T. It is the factor that translates the myriad of human actions over and above population and economics into environmental impacts. Research on the driving forces of global environmental change is, then, research on why T varies from nation to nation and over time.

This simple model has proven very influential. It is true by definition and, therefore, provides a basis for making simple projections of environmental impact under various assumptions about changes in population,

affluence and 'technology'. But it is less useful as a method of assessing the causal influence of population, affluence and other factors on environmental impact. The accounting equation assumes a direct proportionality between population and impact and affluence and impact, e.g. a 10 percent increase in population will produce a 10 percent increase in impact. The causal relation is assumed rather than tested. In addition, all four of the variables used in the model – impact, population, affluence and technology – are undertheorized (Dietz and Rosa, 1994) and the definition and operationalization of each are taken as unproblematic. Yet the IPAT formulation is appealing because it does allow for a decomposition of the forces driving human impacts on the environment into their components. And its functional form is appealing: impact is seen as population times per capita affluence (or total affluence), multiplied in turn by the total amount of impact that occurs per unit affluence.

Several recent studies have built upon the IPAT model by expanding the decomposition to include more terms and thus capture greater complexity, and by allowing for interactions among population, affluence and technology. For example, Bongaarts (1992), Cramer (1995), Kolsrud and Torrey (1991) and Preston (1996) all use variants of IPAT to examine the effects of population growth on environmental quality in an effort to bring IPAT closer to social reality.

Following the same lines of reasoning, we have developed a reformulation of the IPAT model that we call STIRPAT for *ST*ochastic *IMP*acts by *REG*ression on *P*opulation, *A*ffluence and *T*echnology (Dietz and Rosa, 1994, 1997a, 1997b). The model specification is:

$$I = aP_i^b A_i^c T_i^d e_i$$

As the term 'STIRPAT' implies, the model is a descendant of the IPAT model.²⁴ It preserves the multiplicative logic of the IPAT model and the familiarity of that model to environmental scientists. But we move beyond it by disaggregating P, A and especially T and by using regression methods to estimate and test hypotheses.²⁵

The STIRPAT model links work in the environmental sciences with the broad sociological tradition in both theory and research. It breaks two constraints of the IPAT model. First, rather than assuming causal linkages between impact and the right-hand variables, STIRPAT treats such linkages as hypotheses to be tested. Second, STIRPAT encourages elaborating the terms in the model. Rather than leaving T as a 'black box' that balances the IPAT equation, the STIRPAT model encourages consideration of cultural, institutional and political factors as drivers of environmental impact. As we show later, this allows a link between the models of climate change being developed by biophysical scientists and the insights of sociological theory.

In addition, population and affluence can be decomposed into forms that have more social meaning. For example, it is important to distinguish the environmental effects of the number of household units from the average size of such units. The product of these two factors is population size, but each component may have independent effects on the environment and for many environmental problems the number of households may be more consequential than the number of people (Cramer, 1995). That is, the dynamics of household formation may drive CO₂ emissions more than the dynamics of fertility and mortality. The emerging debate about the environmental impacts of consumption also can be understood by decomposing affluence into consumption and other components (Dietz and Rosa, 1997b). The STIRPAT approach facilitates examining these and other elaborations on the basic IPAT model.²⁶

While the STIRPAT model can be applied to any environmental impact, our initial application of the basic model is to GCC. In particular, we have used the model to estimate national CO₂ emissions (Dietz and Rosa, 1997a). We find two interesting results. One is that there appear to be diseconomies of scale at the largest population sizes: countries with the largest populations have a disproportionate impact on CO₂ loads. This finding is novel, and deserves further exploration particularly in relationship to arguments regarding disarticulation in dependent societies (Amin, 1977). We also replicate findings by economists that suggest an environmental Kuznets curve. Several studies have argued that as affluence increases, environmental impact per unit affluence decreases, producing an inverted 'U'-curve, or a Kuznets curve after the relationship between development and inequality posited by Simon Kuznets.²⁷ Why does this occur?

Development Theory

Economists argue that environmental quality is a luxury good that is not of much interest until societies reach a high level of affluence. This argument directly parallels classical development theory in sociology and Inglehart's (1995) postmaterialist thesis in political theory. The curvilinear relationship between impact and affluence obtains because a threshold is reached where willingness to pay for environmental protection becomes greater than the costs associated with achieving it, or because competing risks to health, safety and well-being have been sufficiently reduced that environmental quality becomes the next societal priority. In this formulation, Inglehart's hypothesis specifies the social-psychological mechanism underpinning the societal shift. It is also possible that shifting consumption patterns that accompany greater affluence will lead to reduced impact and dematerialization (Stern et al., 1997). As the ratio of information to material in goods consumed increases, and as information

per se becomes an ever more important consumption good, environmental impact will decrease.

A less optimistic explanation is that the new international division of labor has shifted the most environmentally disruptive activities to the least affluent nations, leaving relatively clean service industries in the most affluent nations. Reduced environmental impact from industries in the affluent nations is thus an artifact of changes occurring for other reasons; the impacts are still taking place, but have been shifted to politically less powerful locations. This 'off-shoring' of impacts opened the way to world systems approaches that look at the global political economy as a driving force behind climate change.

World Systems Theory

As noted earlier, pioneers in world systems theory, including Braudel and Wallerstein, considered climate change a phenomenon of great historical importance in generating social transformation. So we might expect that world systems theory would have carefully examined the causes and consequences of environmental problems over the last quarter century and would provide a useful perspective on the relationship of development to environment. But in fact, as Roberts and Grimes (1997a) have noted in their recent review, world systems theory has largely ignored environmental change as either a cause or consequence of human action. World systems theory is thoroughly materialist and neo-realist, but its emphasis on structural determinants of national actions and conditions seems to have left some of the insights of its founders about the environment, climate in particular, at the periphery of its vision. The environment is nearly as undertheorized in world systems theory as social factors are in the IPAT model.²⁸ Initial attempts to examine environmental degradation in world systems theory treat environmental problems as one more social phenomenon that can be explained with the same variables used to model economic growth, income inequality within a nation or quality of life. The more peripheral or dependent a nation, the more its environment will be degraded, just as peripheral and dependent nations will have slower growth, more inequality and lower quality of life. There is nothing special about problems of the environment in general or climate change in particular.

There are some important exceptions to this current limitation of world systems theory. Bunker (1984, 1985, 1996) has noted that the extraction of 'rents' by exploitation of land and other natural resources can be an important source of profit for capitalists, and can lead to severe environmental degradation in the Third World. These arguments have been taken up by Barbosa (1993) in an examination of Brazilian deforestation. Roberts (1996) has suggested some of the domestic political factors that may influence a

nation's participation in international environmental treaties. And Frey (1994, 1997) has examined the internal factors that make peripheral nations especially susceptible to technological hazards. These efforts provide important starting points for embedding the theoretical insights of the political economy approach within the broader historical and comparative perspective offered by world systems theory. This integration should lead to neo-realist accounts of global environmental change that draw on the insights of both world systems theory and the STIRPAT approach.

Turning to the problem of CO₂ emissions and the Kuznets curve, Roberts and Grimes (1997b) use world systems theory to argue that there is no environmental Kuznets curve that accurately describes the developmental trajectory of national CO₂ emissions. Rather, they conclude that since the oil crisis of the 1970s, affluent nations in the core have become more carbon efficient; that is, they produce more GDP per unit CO₂ emissions. In contrast, the carbon efficiency of middle-income nations has gone down slightly while the carbon efficiency of the least affluent nations has dropped substantially. Thus, the poorest nations are locked into a pattern of high and even increasing environmental impact per unit affluence, while affluent nations may indeed follow the patterns proposed by development theory. If this is true, then any general conclusions drawn from an unconditionalized developmental logic are seriously flawed since only core nations follow the developmental pattern postulated.²⁹

Toward a More Complete Theory

In capitalist societies there will always be pressure to reduce production costs by using the environment – as a sink and as a resource pool – to socialize the environmental costs of production (Gould et al., 1996; O'Connor, 1988; Schnaiberg, 1980, 1994). Indeed, as recent experience in the former Soviet Union and Eastern Europe indicates, any system driven toward growth has a dynamic that promotes adverse environmental impacts. The theoretical question for understanding growth-oriented societies is not: 'When will the environment be exploited?' Rather, the question then becomes: 'Under what conditions will counterforces be adequate to overcome the normal tendency toward environmental disruption?'

In considering this problem, it is critical to remember that climate change is a pure case of a collective good. As a result, climate change may have a different political dynamic than environmental problems that have more localized impacts. Local communities can mobilize against local environmental problems based on common, identifiable interests. Community members and their children will bear the costs of environmental contamination or a loss of resources. Once they perceive this, they can mobilize to reduce environmental impacts. There may be problems of

collective organization, but they are localized. In contrast, climate change is truly a global problem, where local mobilization to reduce greenhouse gas emissions is not very effective unless parallel action takes place literally all over the planet. Thus, the challenge for understanding the driving forces of global environmental impact comes not so much from understanding what drives impacts as from understanding what drives *reductions* in impact. It is here that sociological theory would be a welcome complement to existing formulations.

Developmental theory offers an explanation for reductions in impact that occur as affluence increases – such reductions are thought of as a luxury good. The theory, however, is embarrassed by a variety of evidence suggesting that demand for environmental quality is high even in the less affluent nations of the world. As a result, the postmaterialist thesis is much debated (Brechtin and Kempton, 1994; Dunlap and Mertig, 1995, 1997). It does not appear that development and increasing demand for environmental quality are sufficient to account for variation in environmental impact.

We suggest that the appropriate next move in theorizing the driving forces of environmental change is to examine institutional factors. We see three institutional forms as leading candidates.

1. *Technological infrastructure and capital investment.* The biophysical, economic and technological infrastructure required to adequately detect and moderate adverse environmental impacts can be substantial. Because climate change and many other environmental problems are neither ostensible nor repeatable, and because many of the technologies required to reduce environmental impacts can be complex and require substantial capital investment, we would expect to see changes in impact primarily in those nations where there are adequate resources to detect adverse global consequences and to invest in reducing impacts.³⁰ Many 'soft path' or 'appropriate technology' solutions are cost effective, requiring only indigenous expertise and minimal capital. The choice of technologies that are dependent on imported expertise and capital investment rather than on local resources depends on political forces that are constrained by the factors we describe next.
2. *Environmental values.* Because the effects of climate change are global and the most important effects will occur a half century or more in the future, a concern with climate change must be based, at least in part, on some value commitment to environmental sustainability, such as altruism, and the emergence of truly global and transgenerational concerns. Work on the social psychology of environmental problems theorizes such concerns (Stern and Dietz, 1994; Stern et al., 1993, 1995). Also, recent work has begun cross-national comparisons of such concerns

among the general public (Dunlap and Mertig, 1995, 1997) and has offered a differentiated view of environmentalist ideology that separates instrumental from altruistic concerns (Brulle, 1995).

3. *Political infrastructure.* Even if the public holds relatively altruistic values, and the scientific and technological infrastructure exists to identify and mitigate environmental problems, concern and knowledge must be translated into political action. Roberts (1996) offers some ideas on how structural constraints posed by a nation's position in the global political economy can preclude such actions, as has Frey (1994, 1997). But a fuller theoretical development is required, one that links public perceptions, movement actions, scientific and technology infrastructure and internal political constraints to national and global structures.

Developing such a broader theory will be daunting. However, it has the advantage of integrating neo-realism with a more interpretive orientation and thus joining the two often disparate strands of sociological theory while retaining a form commensurable with research in the biophysical sciences. This link is the sort suggested in recent writings on evolutionary theory (McLaughlin, 1996; Dietz et al., 1990; Eder, 1996; Jaeger, 1994; Jaeger et al., forthcoming; Burns and Dietz, 1992a, 1992b). The basic logic of these approaches is that human actions have biophysical consequences and that these consequences provide feedback to individuals and social systems. But the choice of actions and the interpretation of feedback from the environment depend on both agentic action and structural constraints embedded in culture.

While integration will require considerable effort, the elements needed are coming into place. The STIRPAT research program, for one, disciplines analyses by attending to the biophysical phenomena to be explained – reminding us that sociological models of environmental phenomena must make biophysical as well as sociological sense. The world systems research program draws attention to local and global constraints on environmental protection. The interpretive orientation, as well as work on social movements and public perceptions, focuses on agentic efforts to overcome structural obstacles.

The Interpretive Orientation: Social Construction

The sociological idea that humans exist in socially constructed worlds, enjoying putative success in explaining claims to knowledge in everyday contexts as well as claims to scientific and technological knowledge, is extended by social constructivists to the topic of climate change. With ancient roots in nominalism and idealism and modern roots in phenomenology, social constructivism – as applied to concrete problems – draws

also from the traditions of symbolic interaction, ethnomethodology and historicism (Cole, 1992; Rosa, 1997). The orienting perspective of social constructivism emphasizes the claims-making activities that lead to the emergence and viability of social issues, including science-based ones.

On the topic of climate change there are two distinct constructivist approaches: the first challenges the social authority of scientific knowledge by emphasizing the uncertainties that underpin scientific claims about climate change,³¹ and the second emphasizes the historical, social and political context of claims-making that have elevated the climate change problem to scientific prominence and later to public recognition. The first approach, by pointing to the limitations of the dominant scientific narrative and discourse, opens a wide avenue for alternative inquiries. The second approach represents further demonstration of the social and political forces that shape scientific knowledge claims and public response to them.

Knowledge Claims of Climatic Science

Two contextual conditions of climate modeling enliven the first approach. On the one hand is the recognition that the models underpinning climate change are embedded with considerable uncertainty, as noted above, and this is an established fact that even the most devoted model advocates would not deny. Other scientific uncertainties add further indeterminacy, thereby mitigating the force of claims that climate change has already occurred or can be expected to occur in the future.³² Nevertheless, for the natural scientific community in general, and the modeling community in particular, the models remain at the pinnacle of a hierarchy of knowledge domains that presupposes a natural science agenda (Shackley and Wynne, 1995). That practice, according to this social-constructivist approach, has the undesirable effect of relegating the anthropogenic driving forces – including social, cultural, political, economic and even moral ones – to peripheral consideration. On the other hand, the anthropogenic impacts of and human adaptations to climate change are similarly subordinated to the reigning scientific paradigm and to the needs of computer models. The second-order effect of both of these consequences is to preclude open debate on the assumptions about these forces that are embedded in models and other natural science products.

One technique for the subordination of anthropogenic factors is to call them policy issues, thereby denying their scientific status (Shackley and Wynne, 1996). Yet, it is these anthropogenic factors that lie at the center of any climate change that may be occurring. The relegation of anthropogenic factors to a subordinate role also, in effect, relegates the potential contribution of the social sciences to the same subordinate role. This problem should be addressed and solved, according to this constructivist

approach, by flattening the structured hierarchy of knowledge domains (Shackley and Wynne, 1995) and by incorporating the social sciences at the very foundation of climate change research (Wynne, 1994) – a conclusion shared by other constructivists (von Storch and Stehr, 1997).³³ Key recommendations by von Storch and Stehr are for the crucial need to incorporate into climate models themselves changing social preferences, changing definitions of welfare and conflict over these issues between stakeholders.

Social Context of Knowledge Claims

The second approach of social constructivism, as noted earlier, is to trace the emergence of concern over climate change and examine how that emergence is shaped by historical, social and political forces. The approach divides itself into two parts: the first examining the emergence of scientific concern over the problem, and the second examining the subsequent rise in public awareness and concern.

Hart and Victor (1993) trace the emergence of US policy on climate change research for the period 1957–74, with particular attention to the activities of the scientific elites who labored to elevate climate research to a national and then international policy concern. The time frame of their study, beginning with the International Geophysical Year (IGY) of 1957–8 and ending in the year of the first scientific papers on the ozone hole (1974), covers the period when attention to climate change was sustained by an elite group of scientists, but when there was no sustained policy or regulatory response to these claims. Throughout most of this period, concern about a greenhouse effect did not enjoy independent legitimacy, but was sustained by ‘piggybacking’ it to other policy issues. For example, during the early 1950s research support for climate change was linked to nuclear weapons testing (at the time it was thought that testing would alter climate) and other military objectives. Radioactive tracer studies during nuclear tests showed that not all the released CO₂ would be absorbed by the oceans, leading to investigations of what the residual CO₂ might do to climate.

Taking advantage of the symbolic capital the IGY provided, elite climate researchers were able to establish institutions for continuing research on anthropogenic climate change, such as the National Center for Atmospheric Research (NCAR) in the USA in 1960. Despite this early success, the cadre of elite scientists failed to attract serious public or policy attention – including the generous funding that typically accompanies policy and regulation – because the greenhouse effect was narrowly defined as part of an energy problem. So defined, the consequence was to constrain interest in the topic to the fossil fuel production of CO₂ alone, rather than including the other greenhouse gases and related concerns such as ozone

depletion to be part of the focus. As a consequence of this policy inattention, climate research proceeded on limited budgets and in fits and starts throughout the 1960s.

The emergence of environmentalism in the early 1970s in the USA and elsewhere provided the needed context and momentum for climate researchers; it 'helped [them] to define anthropogenic climate change as an environmental issue; in the process, they broadened the scope of environmentalism, and secured public resources for research on the problem' (Hart and Victor, 1993: 661). The important claim to note here is that now the topic of climate change began to attract serious policy attention, not due to a demonstrably increased scientific understanding of its complex processes, but due to a coalescence of historical, social and political events – and to the strategic responses of scientific elites who seized on this window of opportunity. Thus, the elevation of climate change to independent legitimacy and policy concern is seen as having little to do with scientific knowledge, but mostly to do with the constructions by scientific elites taking advantage of other, often unrelated, policy arenas.

How did concern over GCC become a social problem and part of public discourse? This question guides the second part of the issue of how history, social and political forces shaped the emergence of GCC as a social problem. Mazur and Lee (1993) provide a compelling empirical basis for addressing the question.³⁴ As an extension of a sustained research program (Mazur, 1981) devoted to the question of how scientific, technological and environmental issues become translated by the scientific elites studying them into publicly recognized social problems, Mazur and Lee show once again the importance of historical context and the pivotal intervening role of the media in public recognition. GCC reached the public agenda via the active promotion of influential scientists, by the media's receptivity to the promotional efforts, and by its fit into a general fabric of environmental concern that wove together strands of loosely related environmental problems. Indeed, because GCC's public recognition is the product of this constructive process, and because that recognition is so critically dependent upon media coverage, there is every expectation that with the inevitable decline in coverage there will follow a decline in public concern – quite independent of the validity of scientific knowledge claims about GCC.

Ungar, too, addresses the issue of how scientific claims reach and are absorbed by lay publics (Ungar, 1992, 1995), but with an emphasis on an intervening variable other than media – the impact of 'scare'. In this view, claims-making attracts widespread public attention only when the 'real-world' events underpinning the scientific claims about these events 'unleash authentic social scares' (Ungar, 1992: 483). Science provides the framing and discourse for the problem and scientific elites promote the discourse. But these efforts are only successful if they are accompanied by

dramatic, real-world events where lay-persons can cognitively connect the discourse with their own experience. The drama of the events 'scares' the public into recognizing the grounding of the events in reality and into increasing their receptivity to policy action. It is this reasoning that supports Ungar's claim that decades of global warming research failed to attract public attention until the summer of 1988, when this unusually warm, drought-filled summer created the requisite social scare.

Taken together, the work of Mazur and Lee and that of Ungar suggest that public and policy concerns with global warming are dependent upon events largely independent from the scientific understanding of climate. Instead, public and policy concerns depend upon events from the social and physical environments that stimulate media coverage and which convey a signal that the public should be scared. For Mazur and Lee the sustainability of public concern over global warming will be dependent upon chance historical events that can be connected to greenhouse gases and which stimulate media coverage, while for Ungar it is crucial that those events be extreme enough to generate acute social scare. Thus, to the question, 'what is the long-term viability of global warming as a social problem?' both answer 'it depends': it depends, that is, upon the occurrence of contingent exogenous events that are reminders of the threat of climate change. Since that occurrence is uncertain, so too is the long-term public concern with global warming.

Conclusion

We organized our analysis around three questions. In answer to the first question – asking about intellectual antecedents to contemporary concerns about GCC – we traced threads of the climate–society link to the very beginning of the written word. We outlined the many centuries of speculation of how climate shapes the patterns of social life and the recent centuries of speculation of how social life – the anthropogenic sources – shapes climate. Clearly, there are myriad precursors to modern climate concerns. These historical adumbrations of the climate–society connection have given way to a more refined focus and a greater urgency in contemporary times.

To the second question – about contemporary sociological responses to the prospect of GCC – we identified two broad orientations: a neo-realist orientation and an interpretive orientation consisting of social constructivism. The first orientation launched two research programs investigating the climate–society link. One of these takes seriously the methods of science, borrows directly from the science of ecology, adds sociological insight, and produces empirical results that are a starting point for disciplining debates. From the science of ecology the simple IPAT accounting model first suggested by Ehrlich and Holdren (1971) was borrowed and

reformulated within a more sophisticated conceptual and empirical frame. We relabeled the reformulated model STIRPAT to underscore its markedly different format and to avoid future confusion between the two forms.

The second research program is steeped in the traditions of political economy. It draws on the long tradition of world systems analysis and, in particular, on the wealth of theoretical and empirical work attempting to explain the continuum between the most affluent capitalist nations and the Third World. To develop this explanation this research program has examined the role of various system variables: multinational capital, global political and economic institutions and global and local elites who shape the politics and economies of Third World nations. The result has been a series of explanations for growth, stagnation and inequality between and within nation-states. This line of research is beginning to consider problems of the environment (especially impacts) by offering parallel explanations to those proffered to account for the political, economic and social-structural differences between nation-states.

The second orientation, the idealist-based social constructivism, has pursued the topic of GCC with two separate, but complementary approaches: one that highlights the uncertainties in the knowledge claims of climate scientists (and argues for greater social-scientific involvement at the core of research), and the other that demonstrates the influence of social and political forces on scientific and then public recognition of climate change as a viable problem.

To answer the third question – about the future directions of sociological analysis of the climate–society link – we revisit Elzinga's observations that climate models, such as the general circulation models (GCMs) 'are heuristic devices rather than reality maps' (Elzinga, 1997: 79). The operant term here, 'heuristic', is defined by a leading American dictionary (*Random House Dictionary*, 1987) to mean 'serving to indicate or point out; stimulating interest, as a means of furthering investigation'. No term is more apt to describe the stimulus for a sociology of climate change and for its future work. For, indeed, the prospect of an anthropogenic disturbance of global mean temperature provided by the GCMs has stimulated the two broad orientations to sociological research described here – although they coexist across a broad divide.

The first orientation, underpinned by a version of neo-realism, is more forgiving of the uncertain state of climate models, choosing instead to treat them as a point of departure for expanding our understanding of the dependence of social systems on ecosystems and vice versa. One approach toward accomplishing this is the STIRPAT research program with its grounding in traditional science. We argue that STIRPAT is not only simple and systematic, but also robust – capable of addressing a wide range of environmental impacts and capable of incorporating other

driving forces. Because of this robustness we further argue that this research program holds promise for cumulative findings within a disciplined framework.

The second research program, in the political economy tradition, interjects the ideas of power and inequality into discussions of GCC. Recent work is beginning to develop a distinctive theory of environmental impacts that is reminiscent of the provocative work on climate by the founders of this tradition. We have suggested some ways in which this theoretical development can move forward – by developing a theory of the conditions under which environmental impacts will be constrained. We believe that the world systems and STIRPAT research programs will converge as the former becomes more attentive to a functional form (in theory and statistical model) that incorporates the biophysical processes of STIRPAT, and as the latter continues to point its research program toward incorporating the more complex social and political processes of world systems theory.

The second orientation, underpinned by the neo-idealism of social constructivism, has seized upon the considerable uncertainties in the production of GCMs as an exemplar of socially constructed scientific knowledge. For constructivists, the models are so fraught with uncertainty, the data upon which they rely are so limited and missing key variables, such as cloud behavior, are so crucial that conclusions about climate change are judged to be highly problematic. In essence, the models are seen to reflect scientific beliefs about the world, thereby creating nature rather than faithfully mapping it. The models have, therefore, been an important stimulus for challenging the authority of science via an examination of their assumptions and omission of important variables. They have also been useful for demonstrating the importance of social and political forces in shaping model development.

Promising directions of future research within this orientation include the active involvement of social scientists in the process of refining climate models, in sensitizing climate scientists to the vast social and historical uncertainties the model assumptions about human actions subsume, and in collaborating across disciplines in order to deepen our understanding of human–environment interactions. The promise for the second approach within this overall orientation is, doubtless, an even more challenging one: to demonstrate a link between the social and political forces driving climate research and the cognitive content of climate science, or between the culture of science and the validity of its knowledge claims.

The Future of the Sociology of GCC

At the heart of the distinction between the research on GCC between the neo-realists and constructivists is the issue of cognitive content. The goal

of the neo-realist research programs is to make scientific or substantive contributions to GCC and other global environmental change issues. In pursuing its goal this orientation holds out promise for not only contributing to our understanding of human-environment interactions, but also for the further development of sociological theory. Furthermore, because the research programs are grounded in coherent frameworks they offer the further hope of cumulative knowledge.

Social constructivists, as noted above, have taken two approaches to GCC. The first approach challenges the cognitive content of climate models, argues for the greater involvement of social science, but – unlike the neo-realist research programs – leaves that involvement unspecified. The second approach has virtually no interest in the issue of whether scientific knowledge claims are valid. For example, Ungar writes: 'Constructionists thus focus on claims-making activities, asking not what makes a claim valid but what makes it viable' (Ungar, 1992: 484). As a consequence of this position, there is little attention to whether sociology can contribute scientific or substantive knowledge to an understanding of the environment.

As a context for observing the dynamics of claims-making, the environment for most constructivists is a useful vehicle for demonstrating the applicability and breadth of the constructivist perspective. The environment provides intellectual opportunity. It becomes the arena where claims-making is dynamic and contested, and therefore worthy of investigation. One very real threat with the constructivist approach to GCC, implied in the work of Mazur and Lee (1993) and Ungar (1992), is that it will fall prey to the 'issue-attention' cycle where the environment is abandoned for more fertile or more avant-garde topics to deconstruct.

Despite the fundamental meta-theoretical differences between the two contemporary sociological orientations to climate change and despite their separate goals, both are valuable at this, the incipient stage of our sociological understanding of GCC. Each addresses an important, but different facet of this multifaceted topic. Thus, more crucial than arguing for the exclusive aptness of one or the other in understanding the climate-society link is to argue for the continued engagement of sociologists from a variety of perspectives. This offers our best opportunity for understanding and contributing to this important and challenging topic.

Notes

Our appreciation goes to the following people who have provided comments and criticisms of earlier versions of this article: Katie Bagby, Riley Dunlap, Lori Hughes, Nathan Lauster, Aaron McCright and Ellen Omohundro.

This work was supported in part by National Science Foundation grants SES-9109928 and SES-9311593, John Pierce, Dean of Liberal Arts at Washington State

University and by funds from the Edward R. Meyer Distinguished Professorship in Environmental and Natural Resource Policy of the Thomas F. Foley Institute of Public Policy and Public Service, Washington State University.

1. Exceptions are the so-called 'extremophiles' that inhabit suboceanic thermal vents, hot springs and other very harsh environments that exist within geophysical processes largely independent of the Earth's climate regime.
2. Current CO₂ concentrations in the atmosphere are estimated to be 360 parts per million by volume (ppmv), which is higher than any time in the 160,000 years for which there are ice core measurements and substantially above the 280 ppmv in 1750 (Boden et al., 1994).
3. Chlorofluorocarbons (CFCs), principally due to aerosol emissions, are another, less significant greenhouse gas.
4. Despite the considerable uncertainties just noted, and despite the underdetermination of climate science, 2500 economists (including seven Nobel laureates) (Hinrichs, 1997) and another 2600 natural and social scientists (Sims, 1997) have signed a statement of agreement with this conclusion, stating further that the scientific evidence is sufficient to justify action.
5. It is well known that in the 10,000 years since the beginning of the agricultural revolution the Middle East experienced considerable variation in climate. The climatic fluctuation is correlated with key indicators of ecological change, such as the rise in levels of the Mediterranean and other seas; '... these indicators suggest that the transition between the Byzantine domination of the Middle East and the Arab incursion around 700 CE was not the cause of the desertification of the Negev and coastal plain of Israel. Rather, a drier and warmer climate was probably the primary force behind the decline of rain-fed agriculture in this part of the Middle East. Socioeconomic changes followed only after the land was no longer arable' (Issar, 1995: 352).

This causal sequence of events is consistent with the history of migration and settlement patterns. 'In the Middle East, the warmest and driest periods of the past 5,000 years are coincident with the largest invasions of desert tribes into sown lands and the desertion of cities along the margins of the desert. In contrast, cool and humid periods may be associated with the creation of cities and agricultural economies' (Issar, 1995: 355).

6. 'Instead of progress it is degeneration that may be observed on all sides. We see nothing but the material subversion of the climate and the political subversion of society. As I am writing at this very moment, June 1, 1822 there are two striking effects of subversion that may be distinguished' (quoted in Beecher, 1986: 188).
7. The idea that climate influences the social world even found its way later into the mainstream of classical sociological thought in the work of Pareto. Pareto's goal was to develop a social system explanation of society based upon general equilibrium theory. To construct this system he first explicated its key elements; among them was climate (Pareto, 1935: Vol. IV).
8. Among those contributing to this rejection was the distinguished sociologist W.I. Thomas, who in the first edition of his *Primitive Behavior: An Introduction to the Social Sciences* (1937) recognized theories of this genre but argued that the notion of 'culture area' was more important than natural environment.

9. Within the overall balance at a global level have been variations in surface climate resulting in geophysical impacts such as various ice ages or the desertification noted in the Middle East.
10. Arrhenius won the Nobel prize in chemistry in 1903 for his work on the theory of reaction kinetics.
11. Lecturing in 1896, Arrhenius estimated that this doubling of CO₂, due to fossil fuel burning, would take 3000 years (Uppenbrink, 1996).
12. Climate is even implicated in the spread of plague, for hot summers could have led to the multiplication of rat and flea populations, the principal carriers of plague.
13. According to Braudel (1979: 49): 'There was a general cooling down of the northern hemisphere, for example, in the fourteenth century. The glaciers advanced, ice-floes were more numerous and winters became more severe. The Vikings' route to America was cut short by dangerous icebergs. . . . This climatic drama appears to have interrupted Scandinavian colonization in Greenland; the bodies of the last survivors, found in the frozen earth, are thought to be poignant testimony of this.'
14. One direction is empirically driven research, stimulated by scientific interest in the topic, but steering clear of addressing the scientific credibility of claims about climate change. The interest, instead, is about the level of public awareness and concern over climate change and its perceived causes. This genre of research includes both in-depth, ethnographic studies (the most comprehensive being Kempton et al., 1995) and surveys of the general public (Rudig, 1995), including cross-national comparisons (Dunlap, 1996). Despite its importance in extending our understanding of public awareness of environmental issues, this body of research is only obliquely concerned with climate change and, therefore, not discussed as a separate perspective.
15. This distinction is evident in one of the first collections on the sociology of the global environment, where, in their attempt at even-handed coverage, the editors 'tried to secure an appropriate balance between critical self-reflection, on the one hand, and direct demonstration of the substantive insights which can already come from the application of social scientific methods and concepts to environmental issues, on the other' (Redclift and Benton, 1994: 2).
16. A large volume of writings in the social studies of science tradition, including Kuhn's classic *The Structure of Scientific Revolutions* (Kuhn, 1970), treat the content of science as an undifferentiated whole. This has the undesirable effect of conflating the divide between established and emergent scientific findings. Cole (1992), recognizing this shortcoming, seeks to unpack the whole by distinguishing between what he calls 'core' and 'frontier' knowledge. Our tripartite distinction borrows Cole's idea of 'core' and 'frontier', but adds the term 'horizon' for a new, third category not contained in Cole's scheme.
17. For a variety of reasons, but especially owing to a lack of data, the conditions of ostensibility and repeatability are sometimes even absent from core pursuits, thereby rendering them amenable to social constructivism.
18. The 'no regrets' strategy also underpinned the 1992 Framework Convention on Climate Change at the Rio Earth Summit (Ungar, 1995).
19. At least one version of social constructivism not only endorses this argument,

- but takes it much further. For example, Brian Wynne, one of the leading intellectuals in that tradition, argues 'that the policies most likely to help in combating global warming are worth doing anyway, on social, political, moral and even economic grounds, regardless of what they may or may not do to the environment' (Wynne, 1994: 188).
20. There are also important second-order benefits from reduced pollution. A study reported in the October issue of *Environmental Damage Valuation and Cost Benefit News* identified myriad endpoint costs of pollution: mortality, heart attacks, strokes, hospital admissions, respiratory illness, work days loss, restricted activity days, asthma attacks, IQ changes, hypertension, decreased worker productivity, visibility, household soiling and agriculture (Kerr, 1997).
 21. We focus on national emissions of greenhouse gases here. Analyses can also be conducted at the level of individuals, households, communities and regions. The problems of linking across these levels is reviewed in Dietz and Rosa (forthcoming).
 22. The model, its history and a sociological approach to it are described in Dietz and Rosa (1994).
 23. Sometimes T is described as environmental intensity and is used as the dependent variable in sociological analyses of climate change's driving forces.
 24. We developed the new acronym 'STIRPAT' to distinguish our research program that follows a stochastic formulation from the traditional IPAT with its accounting format. At the same time we wished to grant proper credit to the origins of the idea. We chose STIRPAT because we had 'stirred' the original idea, because it preserved the 'PAT' portion of the original IPAT and because the word 'STIRP' means 'a line of descent from a common ancestor' (*Random House Dictionary*, 1987).
 25. I, P, A and T in STIRPAT are the same as in the original model, namely environmental impact, population, affluence and technology. The subscript _i is added to emphasize that I, P, A and T vary across observational units. The parameters a, b, c and e (the error term) can be estimated with standard statistical procedures.
 26. Dietz and Rosa (1994) and Crenshaw and Jenkins (1996) offer some hypotheses about how the basic IPAT formulation might be expanded to be more consistent with sociological theory.
 27. See Dietz and Rosa (1997a, 1997b) for a discussion and citations.
 28. For example, in Chase-Dunn (1989) environmental problems are mentioned only twice, once in a paragraph summarizing Bunker's work (Chase-Dunn, 1989: 234) and once in passing while dismissing concerns with rapid population growth (Chase-Dunn, 1989: 262).
 29. Krebill-Prather and Rosa (1995) in a detailed analysis of the amount of CO₂ emissions required to produce quality of life, find variation among affluent nations in the trajectory of their carbon intensity, lending further doubt to the developmental logic.
 30. To the extent the environmental movement and environmental science are becoming global, national resources will become less important. But some minimal level of infrastructure is still required to connect with and effectively utilize the global networks.

31. One of the more extreme versions of this approach argues that all physical environments and changes to them, including global warming and other global environmental changes, can be conceptualized as 'landscapes' (Greider and Garkovich, 1994). The concept 'landscape' is defined to mean mediated physical environments, mediated by cultural meaning and identity. Thus, global environmental changes, or problems of the physical environment, are only problems insofar as they are culturally perceived and recognized because in themselves environments lack meaning.
32. A survey of 100 international climate scientists (74 climatologists, 10 glaciologists, 12 meteorologists and four with an unknown specialty) found that a majority believes that anthropogenic greenhouse gases have not yet produced climate change, but can be expected to in the future (Auer et al., 1996).
33. From a similar constructivist perspective, Buttel and Taylor (1992) simultaneously reach complementary and contrary conclusions. They agree, on the one hand, that insufficient attention has been paid by sociologists to global climatic change issues. On the other hand, they argue that those few sociologists already engaged by these issues have too uncritically accepted the claims of environmental scientists. Because of the latter practice, they call for greater sociological participation, not in the collaboration of sociology with other scientists in understanding the global environment, but in the sociology of knowledge effort seeking to understand how the scientific knowledge claims have been constructed by social and political forces. Dunlap and Catton challenge this uncritical acceptance of the social constructivist orientation and the resultant narrowing of the research agenda of sociologists interested in global environmental change (Dunlap and Catton, 1994).
34. The work of Mazur and his colleagues is not, in the strictest sense, social constructivism but in the terminology of Cole (1992) 'realist-constructivist'. It recognizes a reality independent of our perceptions, while also recognizing that our understanding of that reality is subject to the shaping features of social and political forces. See Rosa (1998) for a formalization of this perspective via a demarcation between ontology and epistemology.

References

- Abelson, Philip (1990) 'Uncertainties About Global Warming', *Science* 247: 1529.
- Aldhous, Peter (1990) 'Modest Response to Climate Change Threat', *Nature* 345: 373.
- Amin, Samir (1977) *Imperialism and Unequal Development*. New York: Monthly Review Press.
- Auer, Ingeborg, Böhm, Reinhard and Steinacker, Reinhold (1996) 'An Opinion Poll among Climatologists about Climate Change Topics', *Meteorological Zeitschrift*, N. E. 5: 145-55.
- Barbosa, Luiz C. (1993) 'The World-System and the Destruction of the Brazilian Amazon Rain Forest', *Review* XVI: 215-40.
- Becker, Howard and Barnes, Harry E. (1961) *Social Thought from Lore to Science*. New York: Dover Editions.

- Beecher, Jonathan (1986) *Charles Fourier: The Visionary and His World*. Berkeley and Los Angeles: University of California Press.
- Boden, Thomas A., Kaiser, Dale P., Sepanski, Robert J. and Stoss, Frederick W., eds (1994) *Trends '93: A Compendium of Data on Global Change*. Oak Ridge, TN: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.
- Bongaarts, John (1992) 'Population Growth and Global Warming', *Population and Development Review* 18: 299-319.
- Braudel, Fernand (1979) *The Structures of Everyday Life: The Limits of the Possible*. New York: Harper and Row.
- Brechin, Steve R. and Kempton, Willett (1994) 'Global Environmentalism: A Challenge to the Postmaterialism Thesis?', *Social Science Quarterly* 75: 245-69.
- Bronowski, Jacob (1956) *Science and Human Values*. New York: Harper and Row.
- Bruce, J., Lee, Hoesung and Haites, E., eds (1996) *Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge: Cambridge University Press.
- Brulle, Robert J. (1995) 'Environmental Discourse and Environmental Movement Organizations: A Historical and Rhetorical Perspective on the Development of US Environmental Organizations', *Sociological Inquiry* 65.
- Bunker, Stephen G. (1984) 'Modes of Extraction, Unequal Exchange and the Progressive Underdevelopment of an Extreme Periphery: The Brazilian Amazon, 1600-1980', *American Journal of Sociology* 89: 1017-64.
- Bunker, Stephen G. (1985) *Underdeveloping the Amazon: Extraction, Unequal Exchange and the Failure of the Modern State*. Urbana: University of Illinois Press.
- Bunker, Stephen G. (1996) 'Raw Material and Global Economy: Oversights and Distortions in Industrial Ecology', *Society and Natural Resources* 9: 419-29.
- Burns, Tom R. and Dietz, Thomas (1992a) 'Institutionelle Dynamik: ein Evolutionärer Ansatz', *Journal für Sozialforschung* 32: 283-306.
- Burns, Tom R. and Dietz, Thomas (1992b) 'Socio-Cultural Evolution: Social Rule Systems, Selection and Agency', *International Sociology* 7: 259-83.
- Buttel, Frederick H. and Taylor, Peter J. (1992) 'Environmental Sociology and Global Environmental Change: A Critical Assessment', *Society and Natural Resources* 5: 211-30.
- Chase-Dunn, Christopher (1989) *Global Formation: Structures of the World-Economy*. Oxford: Basil Blackwell.
- Cole, Stephen (1992) *Making Science: Between Nature and Society*. Cambridge, MA: Harvard University Press.
- Cramer, James C. (1995) 'Population Growth and Air Quality in California', paper presented at the Eighth Conference of the Society for Human Ecology, South Lake Tahoe, CA.
- Crawford, Elisabeth (1996) *From Ionic Theory to the Greenhouse Effect*. Nantucket, MA: Science History Publications/USA (Watson).
- Crenshaw, Edward M. and Jenkins, J. Craig (1996) 'Social Structure and Global Climate Change: Sociological Propositions Concerning the Greenhouse Effect', *Sociological Focus* 29: 341-58.
- Dietz, Thomas and Rosa, Eugene A. (1994) 'Rethinking the Environmental Impacts of Population, Affluence and Technology', *Human Ecology Review* 1: 277-300.

- Dietz, Thomas and Rosa, Eugene A. (1997a) 'Effects of Population and Affluence on CO₂ Emissions', *Proceedings of the National Academy of Sciences, USA* 94: 175-9.
- Dietz, Thomas and Rosa, Eugene A. (1997b) 'Environmental Impacts of Population and Consumption', in Paul C. Stern, Thomas Dietz, Vernon Ruttan, Robert H. Socolow and James Sweeney (eds) *Environmentally Significant Consumption: Research Directions*, pp. 92-9. Washington, DC: National Academy Press.
- Dietz, Thomas and Rosa, Eugene A. (forthcoming) 'Human Dimensions of Global Change', in R. E. Dunlap and W. Michelson (eds) *Handbook of Environmental Sociology*. Westport, CT: Greenwood.
- Dietz, Thomas, Burns, Tom R. and Buttel, Frederick H. (1990) 'Evolutionary Theory in Sociology: An Examination of Current Thinking', *Sociological Forum* 5: 155-71.
- Dunlap, Riley E. (1996) 'Public Perceptions of Global Warming: A Cross-National Comparison', in *Global Change, Local Challenge*, HDP Third Scientific Symposium, pp. 121-38. Geneva: International Human Dimensions Program.
- Dunlap, Riley E. and Catton, William R., Jr (1994) 'Struggling with Human Exceptionalism: The Rise, Decline, and Revitalization of Environmental Sociology', *The American Sociologist* 25: 5-30.
- Dunlap, Riley E. and Mertig, Angela G. (1995) 'Global Concern for the Environment: Is Affluence a Prerequisite?', *Journal of Social Issues* 51: 121-37.
- Dunlap, Riley E. and Mertig, Angela G. (1997) 'Global Environmental Concern: An Anomaly for Postmaterialism', *Social Science Quarterly* 78: 24-9.
- Eder, Klaus (1996) *The Social Construction of Nature*. London: Sage.
- Ehrlich, Paul R. and Holdren, John P. (1971) 'Impact of Population Growth', *Science* 171: 1212-17.
- Elzinga, Aant (1997) 'From Arrhenius to Megascience: Interplay between Science and Public Decisionmaking', *Ambio* 26: 72-80.
- Frey, R. Scott (1994) 'The International Trade in Hazardous Wastes', *Journal of Environmental Systems* 23: 165-77.
- Frey, R. Scott (1997) 'The Export of Asbestos to the Peripheral Zones of the World Economy', paper presented at the Annual Meeting of the American Sociological Association, Toronto, Ontario, Canada.
- Gould, Kenneth A., Schnaiberg, Allan and Weinberg, Adam S. (1996) *Local Environmental Struggles: Citizen Activism in the Treadmill of Production*. New York: Cambridge University Press.
- Greider, Thomas and Garkovich, Lorraine (1994) 'Landscapes: The Social Construction of Nature and the Environment', *Rural Sociology* 59: 1-24.
- Hansen, James E. (1996) *Geophysical Research Letters* 15 June.
- Hart, David M. and Victor, David G. (1993) 'Scientific Elites and the Making of US Policy for Climate Change Research, 1957-74', *Social Studies of Science* 23: 643-80.
- Herder, Johann Gottfried (1969) *J. G. Herder on Social and Political Culture*, translated, edited and introduction by F. M. Barnard. Cambridge: Cambridge University Press.
- Hinrichs, Doug (1997) '2500 Economists Agree on Risks of Global Climate Change', *Ecological Economics Bulletin* 2: 16-18.
- Houghton, J. J., Meiro Filho, L. G., Callander, B. A., Harris, N., Kattenberg, A. and

- Maksell, K., eds (1996) *Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge: Cambridge University Press.
- Huntington, Ellsworth (1915) *Civilization and Climate*. New Haven, CT: Yale University Press.
- Inglehart, Ronald (1995) 'Public Support for Environmental Protection: Objective Problems and Subjective Values in 43 Societies', *PS: Political Science and Politics* 15: 57-71.
- IPCC (Intergovernmental Panel on Climate Change) (1996) *IPCC Second Assessment: Climate Change 1995*. Geneva: IPCC.
- Issar, Arie S. (1995) 'Climatic Change and the History of the Middle East', *American Scientist* 83: 350-5.
- Jaeger, Carlo (1994) *Taming the Dragon: Transforming Economic Institutions in the Face of Global Change*. New York: Gordon and Breach.
- Jaeger, Carlo, Renn, Ortwin, Rosa, Eugene A. and Webler, Thomas (forthcoming) *Risk, Uncertainty and Rational Action*.
- Kempton, Willett, Boster, James S. and Hartley, Jennifer A. (1995) *Environmental Values in American Culture*. Cambridge, MA: MIT Press.
- Kerr, R. A. (1997) 'Model Gets it Right - Without Fudge Factors', *Science* 276: 1041.
- Kolsrud, Gretchen and Torrey, Barbara Boyle (1991) 'The Importance of Population Growth in Future Commercial Energy Consumption', paper presented at the annual meetings of the Population Association of America.
- Krebill-Prather, Rose L. and Rosa, Eugene A. (1995) 'Cross-National Trends in Material and Societal Well-Being and in Carbon Releases', paper presented at workshop on Global Environmental Impacts of US Consumption: Exploring the Connections, Committee on the Human Dimensions of Global Change, US National Academy of Sciences/National Research Council.
- Kuhn, Thomas S. (1970) *The Structure of Scientific Revolutions*, 2nd edn. Chicago: University of Chicago Press. (Originally published 1962.)
- LeRoy Ladurie, Emmanuel (1971) *Times of Feast, Time of Famine: A History of Climate Since the Year 1000*, translated by Barbara Bray. Garden City, NY: Doubleday.
- McLaughlin, Paul (1996) 'Towards an Ecology of Social Action: Merging the Ecological and Constructivist Traditions', Department of Sociology and Anthropology, Rutgers University, Newark, NJ.
- Mahlman, Jerry (1989) *Current Issues in Atmospheric Change*. Washington, DC: National Research Council.
- Manicas, Peter T. (1987) *A History and Philosophy of the Social Sciences*. Oxford: Basil Blackwell.
- Mazur, Allan (1981) *The Dynamics of Technological Controversy*. Washington, DC: Communications Press.
- Mazur, Allan and Lee, Jinling (1993) 'Sounding the Global Alarm: Environmental Issues in the US National News', *Social Studies of Science* 23: 681-720.
- Montesquieu, Baron de (1962) *The Spirit of the Laws (De l'esprit des lois)*, translated by Thomas Nugent. New York: Hafner. (Originally published 1748.)
- O'Connor, James (1988) 'Capitalism, Nature, Socialism: A Theoretical Introduction', *Capitalism, Nature, Socialism* 1: 11-38.

- Pareto, Vilfredo (1935) *Mind and Society*, 4 vols. New York: Harcourt. (Originally published 1915–19.)
- Preston, Samuel H. (1996) 'The Effect of Population Growth on Environmental Quality', *Population Research and Policy Review* 15: 95–108.
- Random House Dictionary of the English Language* (1987) 2nd edn. New York: Random House.
- Redclift, Michael and Benton, Ted, eds (1994) *Social Theory and the Global Environment*. London and New York: Routledge.
- Roberts, J. Timmons (1996) 'Predicting Participation in Environmental Treaties: A World-Systems Analysis', *Sociological Inquiry* 66: 38–57.
- Roberts, J. Timmons and Grimes, Peter (1997a) 'World-Systems and the Environment: Toward a New Synthesis', paper presented at the International Conference on Sociological Theory and the Environment. Woudschoten, the Netherlands.
- Roberts, J. Timmons and Grimes, Peter (1997b) 'Carbon Intensity and Economic Development 1962–1971: A Brief Exploration of the Environmental Kuznets Curve', *World Development* 25: 191–8.
- Rosa, Eugene A. (1997) 'Modern Theories of Society and the Environment: the Risk Society', paper presented at the Conference 'Sociological Theory and the Environment', the Second Woudschoten Conference, Woudschoten, the Netherlands, March.
- Rosa, Eugene A. (1998) 'Metatheoretical Foundations for Post-Normal Risk', *Journal of Risk Research* 1: 15–44.
- Rudig, Wolfgang (1995) 'Public Opinion and Global Warming', *Strathclyde Papers on Government and Politics*. Glasgow: Department of Government, University of Strathclyde.
- Schnaiberg, Alan (1980) *The Environment: From Surplus to Scarcity*. New York: Oxford University Press.
- Schnaiberg, Alan (1994) 'The Political Economy of Environmental Problems and Policies: Consciousness, Conflict and Control Capacity', *Advances in Human Ecology* 3: 23–64.
- Shackley, Simon and Wynne, Brian (1995) 'Integrating Knowledges for Climate Change: Pyramids, Nets and Uncertainties', *Global Environmental Change* 5: 113–26.
- Shackley, Simon and Wynne, Brian (1996) 'Representing Uncertainty in Global Climate Science and Policy: Boundary-Ordering Devices and Authority', *Science, Technology, and Human Values* 21: 275–302.
- Silver, Cheryl Simon and DeFries, Ruth S. (1990) *One Earth, One Future: Our Changing Global Environment*. Washington, DC: National Academy Press.
- Sims, Kelly (1997) 'Scientists' Statement on Global Climatic Disruption', Washington, DC: Ozone Action.
- Sorokin, Pitirim (1928) *Contemporary Sociological Theories*. New York: Harpers.
- Stern, Paul C. and Dietz, Thomas (1994) 'The Value Basis of Environmental Concern', *Journal of Social Issues* 50: 65–84.
- Stern, Paul C., Young, Oran R. and Druckman, Daniel (1992) *Global Environmental Change: Understanding the Human Dimensions*. Washington, DC: National Academy Press.

- Stern, Paul C., Dietz, Thomas and Kalof, Linda (1993) 'Value Orientations, Gender and Environmental Concern', *Environment and Behavior* 25: 322-48.
- Stern, Paul C., Dietz, Thomas, Kalof, Linda and Guagnano, Gregory (1995) 'Values, Beliefs and Proenvironmental Action: Attitude Formation Toward Emergent Attitude Objects', *Journal of Applied Social Psychology* 25: 1611-36.
- Stern, Paul C., Dietz, Thomas, Ruttan, Vernon W., Socolow, Robert H. and Sweeney, James, eds (1997) *Environmentally Significant Consumption: Research Directions*. Washington, DC: National Academy Press.
- Thomas, William I. (1937) *Primitive Behavior: An Introduction to the Social Sciences*, 1st edn. New York and London: McGraw-Hill.
- Ungar, Sheldon (1992) 'The Rise and (Relative) Decline of Global Warming as a Social Problem', *The Sociological Quarterly* 33: 483-501.
- Ungar, Sheldon (1995) 'Social Scars and Global Warming: Beyond the Rio Convention', *Society and Natural Resources* 8: 443-56.
- Uppenbrink, Julia (1996) 'Arrhenius and Global Warming', *Science* 272: 1122.
- Von Storch, Hans and Stehr, Nico (1997) 'Climate Research: The Case for the Social Sciences', *Ambio* 26: 66-71.
- Wallerstein, Immanuel (1974) *The Modern World System: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century*. New York: Academic Press.
- Watson, R. T., Zinyowera, M. C. and Moss, R. H., eds (1996) *Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge: Cambridge University Press.
- Weart, Spencer (1992) 'From the Nuclear Frying Pan into the Global Fire', *The Bulletin of the Atomic Scientists* 48: 19-27.
- Wynne, Brian (1994) 'Scientific Knowledge and the Global Environment', in Michael Redclift and Ted Benton (eds) *Social Theory and the Global Environment*, pp. 169-89. London and New York: Routledge.

Biographical Notes: Eugene A. Rosa is Professor and Chair of Sociology and the Edward R. Meyer Distinguished Professor of Natural Resource and Environmental Policy at Washington State University. He has been particularly interested in environmental change, and in the development of the STIRPAT research program outlined in this article. Thomas Dietz holds a PhD in Ecology from the University of California, Davis, and is currently Professor of Sociology at George Mason University. He is co-author of *The Risk Professionals*, and co-editor of *Handbook for Environmental Problems, Human Ecology: Crossing Boundaries and Environmentally Significant Consumption*. His current research interests include the problem of valuation in environmental policy, models of cultural evolution and structural determinants of environmental impact.

Addresses: Eugene A. Rosa, Department of Sociology, Washington State University, Pullman, WA 99164, USA. Thomas Dietz, Human Ecology Research Group, Department of Sociology and Anthropology, George Mason University, Fairfax, VA 22030, USA. [email: tdietzvt@aol.com]